

# An Evaluation of the Utility of Commercially Available Modelling and Simulation Tools, Used in Conjunction with Each Other, for Improving Logistics Support to UK Ministry of Defence Urgent Operational Requirements

Jeremy C. D. Smith

Cranfield Defence and Security, Cranfield University, Defence Academy of the United Kingdom, Shrivenham, Swindon, SN6 8LA, UK

[j.c.smith@cranfield.ac.uk](mailto:j.c.smith@cranfield.ac.uk)

## Abstract

The UK Ministry of Defence has invested heavily in acquiring equipment under Urgent Operational Requirement (UOR) procedures. These enable accelerated procurement to fill urgent capability gaps. However, the dominance of time over cost and performance has led to sub-optimal logistics support that has manifested itself in poor system availability, and in support arrangements that do not represent best value-for-money. This paper describes experiments for improving support to UORs, using a range of modelling and simulation tools. The results indicate that there is utility in using general purpose, costing, and inventory optimization tools, in conjunction with each other.

## Keywords:

Urgent Operational Requirements; operational availability; value-for-money; logistics; support; simulation modelling

## 1 BACKGROUND

### 1.1 The Acquisition of UK Defence Equipment: Two Differing Approaches

The UK Ministry of Defence (MoD) spends around £6 billion a year on equipment, and a further £5 billion supporting it when in service [1]. In procuring and supporting this equipment through life (what the MoD terms *acquisition*) it adopts a phased project lifecycle known as the CADMID cycle (Figure 1) which it introduced in 1999 under the Smart Procurement Initiative.

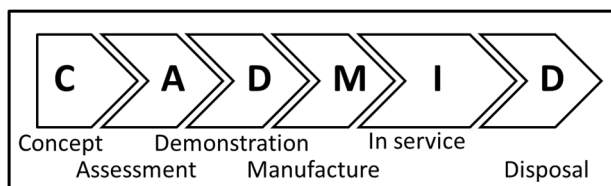


Figure 1: The CADMID Equipment Lifecycle.

In planning for the acquisition of equipment, the MoD uses scenario modelling, analysis of the outputs of research programmes, and whatever it can draw from operational experience. Inevitably, there is considerable uncertainty in this: *'In an unpredictable security environment with constrained resources, planning is complex and involves a high degree of operational judgement'* [2]. In addition, the CADMID cycle can be a very drawn out affair: in his 2009 Review of Acquisition, Bernard Gray found that the average equipment programme overran by 80%, or circa 5 years [3]. Some equipment therefore enters service many years after its envisaged purpose was first endorsed. This leads to situations where the capability of equipment fielded on operations falls short of what operational reality (enemy tactics, hostile terrain etc) demands. In essence, an

operational capability need manifests itself during current or imminent military operations which planning has failed to anticipate. Alternatively, the right equipment is in fact being procured but is still in the C, A, D, or M phases of CADMID and is not yet ready to be fielded. The solution to this problem is to fill the resultant capability gap as rapidly as practicable using what the MoD calls the *Urgent Operational Requirement (UOR)* process. This involves the accelerated procurement of new or additional equipment, or the enhancement of existing equipment, within a timescale that cannot be met by the normal CADMID lifecycle [4]. Recent operations in Iraq and Afghanistan have emphasized the importance of UORs to UK Defence, and their cost: between 2002 and Spring 2011 the MoD spent £6.8 billion on UOR acquisition [5].

Given the urgency of need in a UOR acquisition, speed of procurement and fielding is fundamental to success. To qualify as a UOR it must be demonstrated that the equipment can be procured in time to make a contribution to the operation. This usually demands that it be procured and deployed within 12-18 months, much quicker than is usually achieved in a conventional CADMID acquisition. It must also be unique to an approved theatre of operations, which means that its in-service life may be much shorter than a more conventional CADMID project. The decision to terminate a UOR, or alternatively to transfer it into general service as contingent capability, is a deliberate and often difficult decision. HM Treasury (HMT) will usually only fund sufficient UOR equipment numbers for operational use and pre-deployment training.

### 1.2 The Problem: Operational Availability

The urgent requirement and the restrictions on purchase quantities make it essential that the equipment, once procured and fielded, is available to the front line user in the quantities, and at the time and place, that operations demand. Unfortunately, the levels of operational availability of UORs have suffered. For example, the availability of the Mastiff Protected Patrol Vehicle in Afghanistan was, on average, 23% below the MoD's target between February and October 2008. Another UOR, the Vector patrol vehicle, achieved availability levels on average below 60% [6].

### 1.3 The Problem: Value-For-Money Support

UORs can come at a cost premium, lacking cost-effective support solutions, and being more expensive to operate than equipment procured under normal CADMID processes [7]. The MoD is nonetheless clear that value-for-money considerations are important for a UOR acquisition [8]. However, it also recognizes the lack of understanding of support costs across the Department [9], a failing the National Audit Office (NAO) has also highlighted. They tried to track the movement of spare parts through the supply chain to Afghanistan but were unable to collect information on costs – of parts, storage, or transport. The cost data was unobtainable, leaving them to make the somewhat profound observation that: *'This information gap means that supply chain management decisions cannot be informed by cost considerations'* [10].

## 2 RESEARCH OBJECTIVE

In addition to the lack of understanding of support costs, it is apparent that UOR support failings, manifested in variable and often significantly reduced operational availability levels, are an inevitable result of the UOR process. There are also many other logistics challenges and factors associated with military operations and the military supply chain that are significant. The principal objective of the work described in this paper, was to evaluate the contribution that modelling and simulation could make to helping the MoD address these support failings and wider supply chain factors, thereby better managing the risks that are inherent in the UOR process. To achieve this objective required a realistic and credible UOR support model to be built and a variety of simulation experiments to be conducted.

## 3 THE UOR SUPPORT PROBLEM - FACTORS

### 3.1 Trade-Off and Resultant Support Risk

In a UOR acquisition, of the time, cost, and performance variables, time is the most significant. According to Gray: *'Time is absolutely the dominant factor'* [11]. This brings with it risk, which the MoD accepts, recognizing that it is the level of acceptable risk that differentiates equipment acquisition via UOR procedures from standard acquisition. It accepts that the accelerated timescale of a UOR procurement often leads to delivery of 'the 80% solution' but

cautions its acquisition staff to *'temper the requirement to expedite delivery with the need to ensure supportability'* [12]. The Defence Support Review team advised similar caution, accepting that a UOR should not be delayed by deliberations over support, but stressing that it should be supportable in the near term [13].

Inevitably many UOR procurements are off-the-shelf buys, because there is insufficient time to design and build a solution from scratch. This has led to: *'...bespoke support solutions and disparate fleets with the attendant operational and logistics implications'* [14]. It is usually the case that the MoD integrates additional equipment (e.g. additional armour) onto off-the-shelf purchases in order to make them fully compliant with the UK's operational equipment specifications. This adds further support complexity.

### 3.2 Provisioning, Forecasting, and Supply Chain Pipeline Failures

The NAO identified that of the highest priority materiel demands (classified as 'Priority 01') submitted between June 2007 and November 2008, only 45% from Iraq and 59% from Afghanistan achieved the stipulated target times [15]. Over the period 10<sup>th</sup> December 2009 to 8<sup>th</sup> December 2010, only 35% of Priority 01 demands met the target time to Afghanistan [16]. It attributed these failures to two causes: pipeline failure, and provisioning failure. The former it described simply as being a failure to transport the item in the time stipulated. The latter meant *'... the Department has no stock or a lack of visibility has required a manual search in order to locate it...'* [17]. Alternatively, the item was not ready to be transported to the operational theatre because the demand had not been forecasted, the manufacturer was not under contract to deliver the items within the specified time, or did not have the item in stock [18]. Of the two, the NAO assessed the dominant cause to be provisioning failure.

The incoherence of the MoD's logistics information systems [19] [20] exacerbates the problem. Whilst the MoD tries to hold the right type and quantity of buffer stocks in theatre to allow for supply chain disruptions and for fluctuations in demand, this incoherence makes this very challenging [21]. The Defence supply chain pipeline is also prone to disruption from a variety of causes, including: attack by enemy forces; customs and police interference at border crossings; and natural events, such as the Eyjafjallajökull Volcano eruption in Iceland.

The MoD transports spares utilizing either air or surface movement assets. A combination of failing to forecast spares demand, and the pressure to deliver urgent spares to the operational theatre quickly, has resulted in the MoD making excessive use of the faster, but much more expensive, air transport option. The NAO summarized the issue: *'... improving the Department's forecasting ability is a key requirement for it to be able to increase efficiency, by reducing stocks kept in theatre and through greater use of the slower but cheaper surface routes'* [22].

### 3.3 Recent Initiatives

In an attempt to deliver a predictive capability to the planning of inventories and the locations in which they are held in Afghanistan, and to optimize these inventory holdings, the MoD has introduced the concept of the *Control Tower*. This is a virtual organization which acts as a single MoD focal point, in order to better plan, prioritize, and coordinate the movement of stocks to theatre. A complementary facility is the *Force Primary Depot* which has been erected in Camp Bastion. Its purpose is to: support the optimization of theatre stock holdings; balance the cost of inventory versus the cost of movement; and improve data availability and analysis.

### 3.4 Operational Usage, Engineering and Configuration Evolution

The time imperative, and funding procedures, often result in UORs being procured and deployed in increments. Successive tranches may reflect changes in design, and in maintenance and support requirements, driven by the user having identified operational capabilities in the UOR system different to those originally envisaged. In this sense the User has realized the UOR's 'capability potential'. This process of evolution has operational benefits [23], but the result is an increase to the range of spares and the maintenance burden. The operational usage that a UOR is put to may have a significant effect on its supportability, particularly when that usage changes significantly [24] [25]. For illustration: the poor Mastiff vehicle availability in Afghanistan in 2008 was primarily because of a shortage of key spares, this in turn being the result of a change of usage from on-road protected transport vehicle in Iraq to an off-road pseudo assault vehicle in Afghanistan. *'Once used off-road, the spares level proved inadequate: for example the deployed fleet of 87 Mastiff vehicles consumed an additional 176 axles between December 2006 and January 2008'* [26].

### 3.5 Environmental Factors

The operational theatre's geography and weather can be significant. Reporting on support to helicopters, the NAO observed that greater engine and rotor blade performance was required in the thin air of Afghanistan, and that *'When the sand and dust mixes with oil it becomes a grinding paste, rapidly eroding internal parts; rotor blade and engine lives can be between 75 and 83 per cent shorter when compared to activities in the United Kingdom'* [27].

### 3.6 Commercial and Contracting Practice

UOR equipment is often quite specialist. For example, some unmanned aerial vehicle (UAV) manufacturers are small companies with limited production capacity. As a result the pool of spares available globally is small and the UK has to compete for these spares with the other nations operating the same equipment types [28].

MoD commercial officers are directed to exercise commercial astuteness whilst contracting for UORs. Ideally, MoD project teams procuring UORs need to be able to enter into contracts for support which are

sufficiently flexible to permit their termination at short notice. This requirement, together with the fact that short term extensions to UOR lives may have to be approved incrementally, calls for *'... exceptional commercial judgement to balance costs against the need for contractual flexibility'* [29]. The challenge of exercising commercial astuteness must be considered in the context of a trend for industry contractors to deploy forward to provide depth maintenance in theatre, rather than in the UK. This concept, which MoD refers to as *forward depth*, is a strong theme in support contracting.

### 3.7 Strategy, Policy and Compliance Requirements

The MoD publishes logistics and supply chain policy in its Joint Services Publication (JSP) 886 [30]. It mandates that the UOR support solution includes spares support planning conducted using approved inventory modelling tools. It also sets out the project team's responsibility for ensuring that appropriate arrangements are made for the ranging, scaling, and funding of spares, for identifying critical spares, for ensuring that a manufacturer's spares pack is available to cover initial UOR support requirements, and for ensuring that a contract is in place to cover the longer-term supply of spares. Supply chain risks and issues must be identified.

## 4 DEDUCTIONS: WHAT SHOULD BE TARGETED FOR IMPROVEMENT?

It can be deduced that the aim should be to target improvements to:

1. Achieve improved forecasting of spares demands, thereby: contributing to a better use of strategic transport methods with consequent cost benefits; enabling the *Control Tower* and *Force Primary Depot* to fulfil their purpose; assisting the project teams with provisioning for UORs, thereby enabling them to predict demand better, manage their suppliers better, and be less vulnerable to the inventory supply risks associated with small, specialist, suppliers.
2. Provide greater clarity on how the UOR supply chain could be adversely affected by disruptive events, natural or man-made, thereby enabling more informed risk mitigation strategies to be implemented, such as the holding of buffer stocks.
3. Provide greater clarity on the potential support impacts of a change of UOR usage, and adverse environmental effects, in order to enable better informed risk mitigation strategies.
4. Provide something of utility to MoD commercial officers, to enable them to be more commercially astute, to make UOR support contractual judgements from a better informed position, to comply with policy, and to be well positioned to comply with the *forward depth* support construct.
5. Enable UOR project teams to comply with JSP 886 policy.

6. Enable the MoD to respond to the NAO's observation on the incoherence of its logistics information.

## 5 THE UOR SUPPORT MODEL

### 5.1 Building the Model

In building the UOR support model, identified above as necessary for achieving the research objective, a particular challenge had to be overcome: the identification of, and access to, relevant UOR data, a challenge the NAO has reported on. The solution was to develop a fictitious, but representative, UOR vehicle and use it as the basis for developing the data the model would require. This would also get around the security sensitivity of data associated with real UOR equipment currently deployed. The case study UOR system included a full system equipment schedule, failure rates, appropriate preventive and corrective maintenance actions, and a listing of the spares required to enable such maintenance. The Author developed the case study, drawing on his own experience to inform the work, but ensuring that it was validated independently. It was based on a small, rotary wing, unmanned aerial vehicle (UAV). In building the model, the options were broadly to implement it using one of the simulation modelling developer languages, or to utilize off-the-shelf software. The decision was made to utilize the latter because: the MoD's Simulation Strategy [31] emphasizes the use of off-the-shelf commercial capability; it was considered that every effort should be made to make the modelling process as straightforward as possible in order to encourage its wider use; and given the time imperative it made sense to utilize readily available products.

### 5.2 Choosing the Modelling Products

The decision on which products to use was influenced by what the candidates would be required to model. This included operational scenarios, UOR system operating and support locations, maintenance and spares holding locations, supply chain transit times, and transportation options. It also included costs associated with all of these elements and the support activities associated with an equipment breakdown structure. The fictitious UOR vehicle was developed to reflect a multi-indenture system structure. The software needed to be able to handle a multi-indenture, multi-echelon (MIME) model where spares are allocated to multiple locations (echeloning), and systems, subsystems, components and parts (indenting) can be dealt with as required. Selection of the software to utilize was challenging because research revealed many candidates with similar capabilities. It was not possible in the time available to try them all. The final decision was to select 4 products: *WITNESS* [32] a product which was perceived to offer a general purpose capability able to model the elements of scenario, location, spares quantity and positioning, transit times etc and thus deliver the output of UOR equipment operational availability; *SEER-H* [33] a product which was seen as primarily a cost model

and expected, therefore, to meet the support costs output requirement; and *OPUS10*, used in conjunction with *SIMLOX* [34], products which were expected to deliver the outputs associated with spares quantities and positioning. The fact that the products were licensed for academic usage was also a key influence on the decision.

### 5.3 Designing the Model – Objectives, Inputs, Outputs and Content

The overarching project objective was: *the improvement of support to UORs in order to deliver required operational availability whilst achieving value-for-money*. The focus in using *WITNESS* was *operational availability (Ao)*, this being the product of the time a system is operating, or on standby for operations, as a proportion of total time - made up of operating and standby time, plus the time it is undergoing maintenance and repair, plus the time it is waiting for such repair. In *SEER-H* the focus was on *cost* and *cost drivers*. The purpose was to gain an indication of the magnitude and significance of indicative cost changes, the result of adjusting the model inputs. The rationale for selecting *OPUS10* and *SIMLOX* was, broadly, that having modelled operational availability and cost, *OPUS10* would enable both to be combined to see the indicative *cost-effectiveness* of a range of stock solutions. With *OPUS10*, for a given *stock solution* (i.e., a range and scale of spares, positioned within a supply chain structure), at a derived *cost*, you get a given level of *operational availability*. *SIMLOX* brings the influence of probabilities to the operational availability outputs *OPUS10* provides.

### 5.4 Verification and Validation

Verification and validation of the developed case study system, and of the conceptual model that it underpinned, was carried out by the MoD's Support Chain Optimization Team, in particular members of the team who focused on helicopter platforms. As a result of their observations, the model was adjusted to reflect more realistic failure rates.

### 5.5 The Key Elements of the Model

The key elements of the model are described below, and illustrated at Figure 2.

Some UAVs are deployed in Forward Operating Bases (FOB) in Afghanistan where they are flown on logistic replenishment missions. Operators carry out basic servicing and lubrication tasks and maintainers carry out simple inspection and repair tasks. This is classed as *1<sup>st</sup> line* support. UAVs which experience failures beyond the scope of *1<sup>st</sup> line* are transported back to *2<sup>nd</sup> line* at Camp Bastion. UAVs are also deployed at Camp Bastion where they are used for operator training and to provide a small theatre reserve. The same *1<sup>st</sup> line* tasks are carried out here but, in addition, all *2<sup>nd</sup> line* maintenance and repair tasks – deeper and more complex than *1<sup>st</sup> line* – are carried out in the Camp Bastion Workshop. When UAVs reach a set number of flying hours they are returned to *3<sup>rd</sup> line* (UK factory) for scheduled depth maintenance. This applies to the major mechanical subsystems such as the engine.

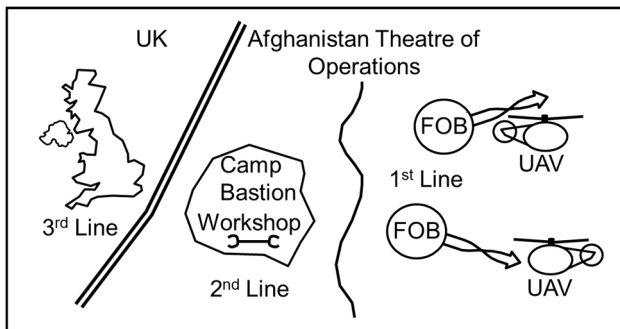


Figure 2: Key Elements of the Model.

Spares and consumables are stocked at the manufacturer in UK, at the Bastion Workshop, and at the FOBs. The manufacturer is currently the sole supplier and ships spares and consumables into theatre utilizing MoD-controlled strategic movement assets and processes. Some UAVs are also deployed in UK for pre-deployment training. The training base is co-located with a combined 1<sup>st</sup> and 2<sup>nd</sup> line maintenance facility. UAVs from this training fleet also go to 3<sup>rd</sup> line when they require scheduled depth maintenance.

## 6 THE EXPERIMENTS

### 6.1 Designing the Simulation Experiments

The validity of the simulation experiments was endorsed by a team of 8 MoD staff, both uniformed and civilian, all of whom were engaged in equipment acquisition, and several of whom had recent Iraq and Afghanistan operational experience. A key focus of the validation activity was the 'base case' as this established the reference point for the comparative analysis of subsequent experiments. The MoD team was invited to adjust the variables in accordance with changing operational and support scenarios which they also validated. They were invited to review and evaluate the outputs from each simulation run in order to deduce the effects on support to the UOR case study vehicle and make changes to the variables for the next run. Their review of the outputs concentrated on operational availability and costs, but it also examined the support cost drivers and other factors. Following each simulation experiment it was possible to identify the changes to the variables which offered most benefit and therefore identify what could or should be implemented in 'real life'. In addition to the Base Case, 7 principal experiments were carried out. These were selected by the 8 MoD personnel as having most validity and potential value. They are described below, together with some observations on their results and their perceived significance.

### 6.2 Change of UOR Usage Resulting in a 50% Increase in Flying Hours (Experiment 1)

The Mastiff UOR illustrates the case for modelling a change of usage for valid tactical reasons, when the result is a reduction in operational availability. This proved to be the outcome when it was modelled on WITNESS to reflect a 50% increase in UAV flying

hours. The enhancements that would have to be made to the support system in order to avoid this reduction in availability were modelled on SEER-H. The outcome was a set of indicative cost increases that could be provided to the project team and to commanders in theatre. The increased UAV usage was modelled on OPUS10 and its output showed a 39% increase to spares cost to achieve a level of operational availability that actually still fell short of the Base Case desired level. This seems to say something about where true value-for-money lies: there would be little point in continuing to procure spares to deliver only marginal availability benefits. An addition to the OPUS10/SIMLOX based experiment involved reducing the supply chain transit time between the FOBs and the 2<sup>nd</sup> line workshop at Camp Bastion in combination with the OPUS10 best solution. This demonstrated that there is more obvious benefit in combining smarter spares procurement with other approaches such as reducing supply chain pipeline times.

Using the tools in combination should enable the UOR project team to model a range of alternative mission profiles and usage patterns, using the results to inform the funding bid in the main UOR business case and to inform its risk management strategy. It could use it to justify identifying alternative spares and spares suppliers, potentially quite a wise course given the limited production capacities of some of the small, specialist UOR suppliers. It could also use it to manage the seasonality that shapes enemy, and therefore UK military, activity levels in theatre, modelling increased activity levels to better inform spares provisioning and positioning in theatre, thereby supporting the MoD's intent for the *Control Tower* and *Force Primary Depot*.

### 6.3 Re-Deployment of UOR Systems (Experiment 2)

Re-deploying UOR systems from UK to theatre in order to counter the system's reduced operational availability has the appeal of being more responsive than buying more systems from the manufacturer. This might make it the logical choice for hard-pressed commanders in theatre who want a quick solution to reduced platform availability. The constrained production capacity of the specialist small supplier also makes buying more systems a less likely option, as does the need to make the case for the purchase against a change of usage that may be only temporary, or seasonal. However, whilst the WITNESS modelling suggested that re-deployment might restore operational availability, it did not come without cost. SEER-H indicated that these costs might be comparatively small, but it should be borne in mind that whilst it might be comparatively quicker to re-deploy UK assets than to buy more, the additional cost, and the logistic complexity, of putting in place the increased spares, maintenance capacities, transport provision, and storage and handling capability that should accompany the re-deployed assets might be prohibitive. Modelling the option on a costing tool should enable the project team to obtain indicative costs for enhancing existing

logistics support capability in theatre as an alternative to the re-deployment of assets from UK. In this way, it might be able to make a more convincing case for not taking what would seem to be the logical decision.

#### **6.4 Procurement of New Systems (Experiment 3)**

The option of buying just 2 more systems was modelled on WITNESS and this improved availability by 11%, suggesting that modelling this option could inform buy quantity if the decision is made to go down this route. However, it would seem that the decision should only be informed by the capabilities of WITNESS used in conjunction with a costing tool like SEER-H. Using the tools in combination this way might enable the project team to refresh the UOR business case successfully, remembering that HMT usually only funds sufficient UORs for operations and pre-deployment training.

#### **6.5 The 'Forward Depth' Logistic Support Construct (Experiment 4)**

Modelling the forward depth support arrangement on WITNESS and SEER-H generated quite impressive results: an improvement in operational availability (73% back up to 87%) and indicative savings of 30%. However, once the MoD and the supplier are committed to this support arrangement in an operational theatre, it is likely to endure until the operation is concluded. This may not sit easily with the MoD's wish for greater support contracting flexibility, seeking value-for-money whilst retaining the freedom to terminate support contracts at short notice should the UOR be discontinued. The modelling suggests that WITNESS and SEER-H, used together, can enable these apparently conflicting messages to be reconciled from a much better informed position, helping commercial officers to exercise the necessary 'exceptional commercial judgement'.

Although the NAO has observed that provisioning is a greater challenge than operating the supply chain pipeline [35][36], 'forward depth' cuts out much of the uncertainty in the UK to theatre supply chain link, making it less vulnerable to disruption by minimizing its use or potentially removing it altogether. Provisioning would also be helped because the supplier is able to gauge more accurately the UOR's usage and support 'reality' on the ground. Positioning the manufacturer at the first point of demand and consumption would seem to satisfy the principle of moving the information decoupling point as far upstream in the supply chain as feasible [37] to provide 'rich' demand information to the manufacturer rather than the delayed, and probably compromised (given the information coherence problems the MoD supply chain currently suffers) information that has to flow over the strategic link from theatre to the UK.

There also appears to be value in modelling a more generic approach to adjusting supply chain pipeline times. What OPUS10 and SIMLOX indicated was that for a given spares solution, implementing measures to change pipeline times on a piecemeal basis may not be the best approach, and that change

applied globally may be most cost effective. In this way modelling on OPUS10 and SIMLOX, or similar tools, appears to be a useful complement to the use of general purpose and cost models. It would seem to endorse the adoption of logistic support constructs that address the supply chain more comprehensively and enduringly. Adjusting individual links in the supply chain would appear to have no such enduring character and be vulnerable, therefore, to changing operational and logistics priorities and the whims of commanders.

#### **6.6 Changes to Maintenance Turn-Around Times (TAT) (Experiment 5)**

Modelling changes to the turn-around times (TAT) of specific subsystems, as was done on SEER-H, should inform where any engineering changes, for example to later variants of a UOR, would be most profitably targeted. In an off-the-shelf system these changes might be only minor but if they are made to large, complex, expensive subsystems they might nonetheless make financial sense. If measurement of a TAT is deemed to include the time to get a UOR to and from maintenance activity, then the associated variables should offer more potential because they contribute to supply chain pipeline times. Modelling on WITNESS resulted in significant improvement to operational availability (+14%), but this result should be treated with caution. The experiment simulated a 50% reduction in TATs at all three lines of support, across all the subsystems of the UAV, a scenario that would have been very challenging to achieve in practice. It would be likely to require the UOR system to be given priority for workshop time and resources over other systems. The supply chain in Afghanistan is vulnerable, and to model on the basis of any degree of certainty in *reduced* pipeline timings is probably not a sound basis for provisioning, positioning spares, and so on.

On OPUS10 and SIMLOX a more pragmatic approach was taken: *increasing* TATs to reflect pipeline vulnerability. Here there appears to be value in modelling to mitigate operational supply chain risk. The NAO identified strategic movement between UK and operational theatres as an important contributor to spares shortages. By simulating delays in strategic movement by increasing TATs at 3<sup>rd</sup> line by a factor of four, OPUS10 indicated not only the increased cost of mitigating pipeline failure, but also the requirement to double engine stocks to hold operational availability at an acceptable level. It appears to be the case that simulation modelling of this type can make a useful contribution to UOR supply chain risk management strategies.

#### **6.7 Change of Failure Rates (Experiment 6)**

The speed of a UOR procurement leaves little time for system trials and testing and to some extent the MoD has to rely on the manufacturer's predicted mean times between failures (MTBF). There is risk in this, particularly for genuinely new capabilities and with the uncertainty inherent in military operations. The logic of modelling more pessimistic failure rates led to Experiment 6 in which failure rate changes

were made to a variety of subsystems on OPUS10. The effects of accelerated wear and tear, the result of adverse environmental conditions, were simulated for those subsystems that were considered to be most vulnerable. The engine, with its rotating mechanical components, was one such system. The results suggested that it should be possible to develop spares solutions that target those most critical, rather than provisioning in a blanket fashion to mitigate logistics risk.

Provisioning should address both spares quantity and location. The UOR project team should be able to use the modelling of failure rate changes to help the MoD's *Control Tower* do its job of balancing spares availability in theatre with priorities for strategic movement by air and surface. The modeller does, however, need to understand what the environmental effects are likely to be in order for the modelling to be valid. This may have to wait until real failure data has been collected in theatre, most likely after the UOR has been fielded and has commenced its sustaining support phase. The OPUS10 results illustrate the fact that smarter spares procurement and positioning might not provide the complete answer. For the engine and for the chassis, despite a 49% and a 31% cost increase respectively, availability still did not reach base case levels. SIMLOX demonstrated how availability was quite sensitive to failure rate changes. A UOR project team, with such modelling outputs, should be able to make the case that if availability is indeed critical, it requires a more comprehensive approach to be taken, probably including changes to the physical 'laydown' of logistics installations in theatre.

#### **6.8 Application of Spares Off-the-Shelf Satisfaction Rates (Experiment 7)**

The value in modelling spares off-the-shelf satisfaction rates (*fill rates*) was seen to lie in the belief that, given the remit not to delay a UOR's deployment by deliberations over support, the quick response, initial, UOR spares solution might well be based on just such a simplistic policy. However, the OPUS10 modelling illustrated that the high expenditure incurred on spares to meet the imposed fill rate (an additional 29%) did not guarantee an increased availability and represented wasted expense because availability actually levelled out. More importantly perhaps, implementing the policy would require that spares are re-supplied to theatre on a sustained basis, thereby burdening an already stretched supply chain both inter- and intra-theatre.

### **7 GENERAL OBSERVATIONS**

#### **7.1 Balancing Quantitative and Qualitative Factors**

In reality, the decisions made during military operations are shaped by many qualitative, interpretive human influences. There has been much media coverage of equipment shortages, particularly those deemed to be safety-critical, and UORs are prime candidates for such attention. It would seem quite probable, therefore, that the MoD's response to

a reduction in the operational availability of a UOR may well include the imposition of questionable blanket policies such as an expensive and logistically demanding globally applied spares fill rate – despite the modelling suggesting a better targeted approach.

Ideally, the positivist, quantitative, outputs from the simulation modelling experiments need to be complemented by some interpretivist subjectivity, the application of qualitative 'overrides' that recognize the less tangible aspects of operational reality. The question of who the customer for the modelling is arises here. It is easy to envisage the UK-based modeller's quantitative logic losing its objective force as it is, metaphorically speaking, transported into the operational theatre. This reinforces the well-established principle that the modeller and the project manager work together.

#### **7.2 Owning the Problem and the Issues of Influence and Control**

According to Robinson [38] simulation modelling should involve the client, the modeller, and domain experts. However, in UOR support there may be particular tensions between the client and the domain experts. The UOR project team leader, nominally the 'client' and owner of the support problem, may be able to use simulation modelling outputs to influence the management of the balance between the forward positioning of spares in theatre and the movement of spares to theatre via strategic transport assets. However, he may have little or no influence, and probably no control, over the physical supply chain itself, and particularly those parts of it in-theatre. Therefore, the experiments which changed the variables relating to supply chain pipeline times may be of limited practical value to the owner of the problem. The domain experts, principally those people deployed on operations, may have a wide variety of other pressures and priorities to manage. The fact that military personnel serve operational tour lengths of between 4.5 and 6 months adds the factor of collective memory fade. Convincing arguments, informed by simulation modelling, made before the UOR's initial deployment may be forgotten about a few months later when people are addressing its continuous, sustaining support.

### **8 CONCLUSIONS AND POSSIBLE FURTHER WORK**

The aim of the research was to evaluate the utility of commercially available simulation and modelling tools used in conjunction with each other. There are no doubt grounds for criticizing the final choice of tools, and there are undoubtedly equally capable alternatives. What mattered, however, was that the benefits, or otherwise, could be evaluated broadly and in this sense the actual costs, operational availability percentages and so on, were not critical in themselves; what mattered was the magnitude of the changes they underwent as the variables were adjusted. The cost outputs suggest that simulation modelling of UOR support has the potential to partially alleviate the NAO's criticism that the information gap results in MoD supply chain



management decisions not being informed by cost considerations. It should enable a UOR project team to conduct the spares planning, using approved modelling tools, that the MoD mandates. It should also enable the team to satisfy the requirement to identify urgent, or critical, spares (e.g. engines). The UAV experiments also seemed to endorse the value of using a mix of modelling and simulation tools to tackle a common Defence problem, the one which Sleptchenko et al [39] modelled: to maximize system availability given a fixed budget for spares and maintenance capacity; and to minimize spending on spares and maintenance capacity given a fixed availability target. This suggests that the use of the tools in this research meets the need for 'generalizability' i.e. that the results can be applied to the support of UORs in general.

Based on the scale and scope of the UAV model, its data, and the experiments conducted, it would seem that the commercial products should meet the MoD's needs for simulation modelling that is quick and effective to meet operational timescales [40]. The tools seemed to be responsive and rapidly re-configurable, as the MoD's simulation strategy, and its expeditionary posture, demand. Using the tools in conjunction with each other was felt to be necessary because no single tool delivers all the required functionality. Arguably, to address a broad problem such as improving logistic support to UORs, it was not just feasible to use a variety of tools in conjunction with each other but actually essential. Those selected for the task seemed to perform well together.

The ideal would have been to be able to draw upon a complete and comprehensive UOR data set, rather than design and build a case study system from scratch. That this was not achievable would be a fair criticism of the research, although the NAO's observations on the poor level of data available to them in their research [41] would perhaps soften the criticism somewhat.

Ultimately, simulation modelling is an aid to decision making and it should never be assumed to provide the answer to any problem by itself. There would seem to be a case for a more deliberate examination of how the quantitative benefits of simulation modelling are complemented by the qualitative variables associated with military operations.

## 9 REFERENCES

- [1] Ministry of Defence, 2010a, The Defence Strategy for Acquisition Reform, Norwich, The Stationery Office Limited.
- [2] National Audit Office, 2004, Ministry of Defence, The Rapid Procurement of Capability to Support Operations. London, The Stationery Office.
- [3] Gray, B., 2009, Review of Acquisition for the Secretary of State for Defence, An Independent Report by Bernard Gray.
- [4] Ministry of Defence, 2011a, Acquisition Operating Framework, Version 3.1.11 – August 2011. [via CD on registration with MoD], Available from: D:\aofcontent\tactical\tlcm\content\uor\uor\_intro.htm [Accessed 15th September 2011].
- [5] National Audit Office, 2012, Ministry of Defence, Managing the Defence Inventory. London, The Stationery Office.
- [6] National Audit Office, 2009, Ministry of Defence, Support to High Intensity Operations. London, The Stationery Office.
- [7] National Audit Office, 2011a, Ministry of Defence, The Cost-Effective Delivery of an Armoured Vehicle Capability. London, The Stationery Office.
- [8] Ministry of Defence, 2011b, Commercial Policy Statement, Urgent Operational Requirements [via CD on registration with MoD], Available from: D:\aofcontent\tactical\toolkit\downloadsindexed\uor\uor\_cps.pdf [Accessed 17th September 2011].
- [9] Ministry of Defence, 2010b, Defence Support Review Phase-1 Report (Refresh).
- [10] National Audit Office, 2011b, Ministry of Defence, The Use of Information to Manage the Logistics Supply Chain. London, The Stationery Office.
- [11] Gray, B., *op. cit.*
- [12] Ministry of Defence, 2011b, *op. cit.*
- [13] Ministry of Defence, 2010b, *op. cit.*
- [14] National Audit Office, 2011a, *op. cit.*
- [15] National Audit Office, 2009, *op. cit.*
- [16] National Audit Office, 2011b, *op. cit.*
- [17] National Audit Office, 2009, *op. cit.*
- [18] National Audit Office, 2011b, *op. cit.*
- [19] National Audit Office, 2009, *op. cit.*
- [20] National Audit Office, 2011b, *op. cit.*
- [21] National Audit Office, 2009, *op. cit.*
- [22] National Audit Office, 2011b, *op. cit.*
- [23] National Audit Office, 2011a, *op. cit.*
- [24] National Audit Office, 2009, *op. cit.*
- [25] National Audit Office, 2011b, *op. cit.*
- [26] National Audit Office, 2009, *op. cit.*
- [27] *ibid.*
- [28] *ibid.*
- [29] Ministry of Defence, 2010b, *op. cit.*
- [30] Ministry of Defence, 2010c, JSP 886 The Defence Logistics Support Chain Manual, Volume 3 Supply Chain Management, Part 10 - The Management of Equipment Procured under Urgent Operational Requirement Arrangements, Version 2.2.
- [31] Ministry of Defence, 2008, MoD Strategy for Simulation (Including Modelling and Synthetic Environments) (A Paper by DAES).
- [32] Lanner: <http://www.lanner.com/>
- [33] Galorath: <http://www.galorath.com/>
- [34] Systecon AB: <http://www.systecon.se/>
- [35] National Audit Office, 2009, *op. cit.*
- [36] National Audit Office, 2011b, *op. cit.*
- [37] Mason-Jones, R. & Towill, D.R., 1999, Using the Information Decoupling Point to Improve Supply Chain Performance. The International Journal of Logistics Management. 10 (2), 13-26.



- [38] Robinson, S., 2008, Conceptual Modelling for Simulation Part 1: Definition and Requirements. Journal of the Operational Research Society, 59, 278-290.
- [39] Sleptchenko, A., van der Heijden, M.C. & van Harten, A., 2003, Trade-Off Between Inventory and Repair Capacity in Spare Part Networks. Journal of the Operational Research Society, 54, 263-272.
- [40] Forder, R.A., 2004, Operational Research in the UK Ministry of Defence: An Overview. Journal of the Operational Research Society, 55, 319-332.
- [41] National Audit Office, 2011b, *op. cit.*